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ADVANCED MARINE TECHNOLOGY

E. E. Hays, et al

Woods Hole Oceanographic Institution

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This is a progress report for the period 1 February 1974 - 31 July 1974 on the following projects in Advanced Marine Technology: (a) Submerged Navigation. (b) Self Contained Ancillary Modular Platform. (c) Modular Acoustic System. (d) Wide Area Illumination.

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TECHNICAL PROGRESS REPORT

ADVANCED MARINE TECHNOLOGY

1 FEBRUARY 1974 - 31 JULY 1974

By

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December 15, 1974

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Approved for Distribution Earl E Hays

Earl E. Hays, Chairman
Department of Ocean Engineering

TABLE OF CONTENTS

Report Summary

The navigation system previously reported on is currently (July 1974) being used by ALVIN in a study of the Mid-Atlantic Ridge as part of Project FAMOUS. According to all reports the system is a most important factor in making the project successful so far.

Engineering design, construction and testing are the main efforts in the subjects summarized below with more detail later on.

(a) Submerged Navigation
High Resolution Pulse-Doppler Navigation System

The necessary elements for this system are nearing a state of completion for a field test from R/V CHAIN during a cruise in September. This system will use two minicomputers aboard CHAIN for data processing - and will demonstrate feasibility, a system for a submersible will require considerable more electronics design so that only one computer is needed.

(b) Self Contained Ancillary Modular Platform

ALVIN's southern schedule and the commitment to Project FAMOUS eliminated any shallow water testing of SCAMP this spring. Work has continued on the optical control system.

(c) Deep Submersible Modular Acoustic System

This system is proceeding on schedule and should see use aboard ALVIN in 1975. The development has changed somewhat from original plans to match computer components that have recently become available. This will make the system easier to operate in a hardware sense.

(d) Wide Area Illumination

Fabrication of a street light to float above ALVIN is proceeding on schedule.

Submerged Navigation

High Resolution Pulse-Doppler Navigation System

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High Resolution Pulse-Doppler Navigation System

Introduction

This report is the first semi-annual progress summary for the High Resolution Pulse-Doppler Navigation System task of the Advanced Marine Technology Program at W.H.O.I. Design, development and construction during this period have resulted in a shipboard operational realization of the Pulse-Doppler navigation system. At sea evaluation trials of the system are scheduled to commence during the next reporting period.

A detailed description of the Pulse-Doppler system objectives is contained in the "Advanced Marine Technology" research proposal submitted to ARPA, 16 July 1973. The system is an evolutionary outgrowth of the ARPA Submerged (pulse) Navigation system and a Doppler tracking system, both developed at W.H.O.I. The initial 16 July 1973 proposal was aimed at a three to four phase program spanning an interval of two and one-half years. Only the first years' effort has been underwritten by ARPA. This interval covers only Phase I of the 1973 proposal. The objectives of Phase I were to

(a) develop a CW beacon and modified pulse transponder,

(b) develop a cycle counter to interface the Doppler tracking receiver with a shipboard processor (HP 2100),

(c) develop a modified pulse receiver,

(d) develop a software package for shipboard computer system operation,

(e) acquire the additional hardware necessary for a fully operational shipboard system,

(f) perform preliminary survey and error analyses,

(g) conduct sea trials of shipboard system,

(h) begin design of a miniaturized version of the system for submersible use.

At this writing tasks (a) through (e) have been completed. Item (f) is in progress. Item (g) will be conducted during the next reporting period. Item (h) will not be undertaken since those phases of the project dealing with the development of a submersible system are not being underwritten.

The following hardware items have been designed and constructed at W.H.O.I.:

1) Doppler Navigation receiver,

2) Doppler Cycle Counter and display,

3) Timing Controller,

4) Auto-Switching Coil Unit.

Of these four, items (1) and (2) are unique to the Pulse-Doppler system. Items (3) and (4) are duplicates of units used in the ARPA Submerged (pulse) Navigation System.

The following items have been specified by W.H.O.I. and were constructed by outside services:

1) Continuous Wave (CW) Doppler Beacons (2 units, Ocean Applied Research,

2) Pulse Transponder Doppler filtering (3 units, AMF Model 324),

3) Pulse receiver Doppler filtering (1 unit, AMF Model 206).

The following items were purchase, unmodified, from outside services:

1) Pulse system coder, power amplifier and transducer (AMF),

2) Mooring equipment (Benthos).

The system components have been integrated into a working Pulse-Doppler Navigation System.

Software has been developed for acquisition and processing of the Doppler navigation information provided by the Doppler receiver and Cycle Counter.

A mooring configuration has been designed that enables simultaneous mooring of the Doppler CW beacons and pulse transponders.

Algorithms are being evaluated to enable optimum Doppler alone and combined pulse-Doppler surveys of the moored beacons and transponders. Computer programs are being developed to implement these algorithms.

This report is divided into three sections:

I. Pulse-Doppler System - General

II. Pulse-Doppler System - Hardware

- A) W.H.O.I. Doppler Receiver
- B) W.H.O.I. Doppler Cycle Counter
- C) CW Doppler Beacons
- D) Pulse Transponder Doppler Filtering
- E) Pulse Receiver Doppler Filtering

III. Pulse-Doppler System - Software

- A) Real-time Pulse-Doppler Processing Software
- B) Pulse-Doppler Survey Procedure

I. Pulse-Doppler System - General

A functional block diagram of the Pulse-Doppler Navigation system is shown in Figure 1. Operation of the pulse portion of the system is identical to the ARPA Submerged (pulse) Navigation system. In essence, navigation is performed by measuring the round trip travel time from a shipboard transducer to a moored transponder. Three transponders allow absolute ship positioning with respect to the transponder net. The Doppler portion of the system measures position relative to previously measured positions by counting Doppler cycle loss or gain during ship translation. Highly stable CW beacons transmit at approximately 13 kHz ($\lambda \approx 12$ cm) so that a change of one Doppler cycle represents translation of 12 cm along the beacon-ship vector. Three beacons yield unambiguous relative position determinations. Relative position accuracy of the pulse system is about $\pm$2-3 m. Relative position accuracy of the Doppler system is less than 0.05 m. Operating together, absolute position within the net of $\pm$1 m should be obtainable, with relative accuracy of about 0.05 m.

II. Pulse-Doppler System - Hardware

A) W.H.O.I. Doppler Receiver (Figure 2)

1) General Information - The Doppler receiver provides analog signal conditioning necessary for proper operation of the digital Doppler Cycle Counter. The receiver has five identical channels for beacons at 12.900, 12.950, 13.000, 13.050 and 13 100 kHz. The receiver is designed as a stand alone unit to be connected directly between receiving hydrophone and the Doppler Cycle Counter. A functional block diagram of the receiver is shown in Figure 3. Beacon signals are received, amplified, filtered, heterodyned, post filtered, quadrature phase detected and low pass filtered. Each beacon, with output

$$s(t) = A \cos (\omega_0 t)$$

is received as

$$s(t) = A(t) \cos (\omega_0 t + \theta(t))$$

where ω_0 is the carrier frequency, and $\theta(t)$ represents Doppler modulation. This signal is represented at the output of the receiver as two components, at base-band, in phase quadrature,

$$x_c(t) = A(t) \cos\theta(t)$$

$$x_s(t) = A(t) \sin\theta(t).$$

The quadrature components from each beacon channel are monitored on small oscilloscopes, and applied to the Cycle Counter.

2) Front Panel - The front panel contains amplifier gain controls and convenient terminals for monitoring receiver operation.

3) Rear Panel - The rear panel contains all connectors for signal input and output to the Cycle Counter.

4) Card File - The receiver is constructed using a card file with 29 slots. Circuit boards can be placed in card extenders for simple adjustment and repair. Major circuit functions are confined to separate cards to allow efficient replacement and modification. The power supplies for all electronics are self-contained.

B) W.H.O.I. Doppler Cycle Counter (Figure 4)

1) General Description - The Doppler Cycle Counter accepts the quadrature beacon signals from the Doppler receiver, and using digital logic, displays, stores, accumulates and conditions Doppler cycle counts for computer input. A functional block diagram of the Cycle Counter is shown in Figure 5. Its logic circuitry computes Doppler cycle loss or gain in increments of ¼ cycle (relative translation of 3 cm) and stores this data in a buffer register for input to the shipboard computer upon command. Doppler cycles (in increments of whole cycles - 12 cm relative motion) are displayed in octal format on the front panel. The Cycle Counter can simultaneously process five channels of Doppler information. The Cycle Counter logic section determines the instantaneous trigonometric quadrant of $\theta(t)$ by examining the signs of $x_c(t)$ and $x_s(t)$. When the quadrant of $\theta(t)$ changes, a bit is clocked into a decimal up-down counter. At front panel selectable intervals accumulated quadrant changes are clocked into a 16 bit storage register, and simultaneously displayed on the front panel. Upon computer command the contents of the storage register are transferred directly to the shipboard computer via a standard 16 bit Input-Output card.

Timing sequences are carefully controlled to prevent missed quadrant changes during clocking intervals, or computer read intervals. Information is transferred to the computer, or display at a 0.1, 0.5, 1, 10 or 100 second rate selectable by front panel switch. Normal operation is at 0.5 seconds. In addition, the Cycle Counter is equipped with a front panel quadrant display which serves to monitor correct operation of the unit. It also has a self-test display on the front panel for monitoring system voltages.

The Cycle Counter can be operated independently from the computer, and as such can serve as a stand alone navigation display. In the accumulate mode (front panel selectable) Doppler Cycle counts are accumulated during ship translation. At any instant the displayed digits indicate the number of whole Doppler cycles of ship translation along the CW beacon-ship vector.

2) Front Panel - The front panel contains function switches, cycle count displays and a self-test display.

3) Rear Panel - The rear panel contains Doppler Receiver input connectors, computer I/O connector and clock frequency input connector. The Cycle Counter requires a 1 MHz TTL compatible clock frequency.

4) Card File - The Cycle Counter is constructed using a card file with 19 slots.

5) Power Supply - Power supplies for the Cycle Counter are mounted on an external chassis.

C) CW Doppler Beacons

CW Doppler Beacons were specified by W.H.O.I. and were constructed by Ocean Applied Research, Falmouth, Massachusetts. The beacon consists of a highly stable oscillator (crystal controlled, oven encapsulated), power amplifier and transducer mounted in a pressure case tested to 20,000 feet. Specifications for the beacons are:

a) Signal Level 66 db re 1 μ Bar @ 1 m

b) Operating Life - 10 days minimum

c) Switch selectable frequencies (12.900 to 13.100 kHz in 50 Hz increments)

d) Frequency stability - 2×10^{-9}

e) Operating depth - 20,000 feet.

D) Pulse Transponder Doppler Filtering

Specifications for making AMF Model 324 pulse transponders compatible with the Doppler system were supplied by W.H.O.I. to AMF, Sea-Link Division, Alexandria, Virginia. Principle modifications of the transponders are to enable them to:

a) Operate within 30 feet of a 66 db continuous tone of specified frequency (12.900 to 13.100 kHz) through the use of notch filtering for tone reject.

b) Operate at a minimum range of 9 km.

E) Pulse Receiver Doppler Filtering

Specifications for pulse receiver filtering were supplied by W.H.O.I. to AMF Sea-Link Division, Alexandria, Virginia for modification of their Model 206 digital pulse receiver. Notch filtering is to be provided to allow operation in the presence of a CW beacon tone when transponder and beacon are mounted together at a range of 9 km.

III. Pulse-Doppler System - Software

A) Real-Time Pulse-Doppler Processing Software

Computer codes have been written to extract hydrophone motion data from quadrant counts supplied to the Hewlett Packard 2100 computer by the Doppler Cycle Counter. Given the beacon locations and the initial hydrophone position in real time.

Quadrant counts are interfaced with the computer through a standard 16 bit microcircuit card and read in with a demand interrupt driver every ½ second. The driver is double buffered to permit display functions to be performed.

The quadrant counts are converted to net motion along the hydrophone-beacon path by

$$\Delta r_i = Q_i f_i / C$$

where Q_i is the cycle count and f_i is the frequency for beacon i. The local sound speed C at the hydrophone depth is used. Ten(10)Hz low-pass filtering limits Δr_i to less than 0.5 m in any ½ second interval. Such small relative motions permit linearized position equations to be used. For the beacon i, the change in location (Δx_i, Δy_i, Δz_i) is

$$\Delta r_i = \Delta x_i \left(\frac{X_i}{R_i}\right) + \Delta y_i \left(\frac{Y_i}{R_i}\right) + \Delta z_i \left(\frac{Z_i}{R_i}\right)$$

where X_i, Y_i, Z_i are the coordinates of the hydrophone relative to that beacon. R_i is the range to beacon i. These equations are solved to obtain the new positions. The range for the next data interval is given by $R_i + \Delta r_i$.

A continual update of hydrophone position is available on a line printer at rates of 2 per second to one per minute. The unprocessed cycle counts are also displayed as a diagnostic aid.

Since the calculation proceeds much faster than real time, the Doppler processing code can be readily added to the standard ACNAV (part of the ARPA Submerged (pulse) Navigation System) software package. Alternatively it is a simple matter to add a plotting capability to the existing program.

The most recent version of the ACNAV software package, interfaced through a separate computer, is being used in the sea test being conducted this fall. This software package includes a sonobuoy mode for tracking of free drifting, radio-telemetered packages.

B) Pulse-Doppler Survey Procedures

Survey procedures have been developed to permit simultaneous use of pulse and Doppler data to obtain locations for the transponder - beacon moorings. The optimum survey uses pulse and Doppler data gathered around the periphery of the transponder net as well as data gathered near its center.

Investigation of combined pulse-Doppler survey techniques has revealed that geometric magnification factors, relating position errors to measurement errors, are minimized for surveys performed outside the net. Since signal-to-noise degrades rapidly outside the net, we have to trade-off desired net size against survey accuracy. Since both transponders and beacons have a maximum slant range of about nine kilometers, we have compromised on six kilometer mooring separations.

An iterative survey procedure is used to find those three-dimensional mooring locations that minimize the errors in range to the survey points. For the estimated mooring locations (X_i, Y_i, Z_i) and the estimated survey points (x_i, y_i, z_i), the range estimates are:

$$R_{il}^2 = (X_i - x_l)^2 + (Y_i - y_l)^2 + (Z_i = z_l)^2$$

The measured ranges are given by r_{il} for pulse measurements and $r_{il} - r_{i0}$, where r_{i0} is the reference survey point, for the Doppler measurement. The iterative program searches for those mooring locations that minimize

$$E = \sum_{l=i, i=1}^{L, I} (r_{il}^2 - R_{il}^2)/\sigma_{il}^2$$

where σ^2_{il} is the variance in the range estimates at the survey point l. The error estimate is weighted by the uncertainty in the pulse or Doppler measurement.

In this procedure a survey point can be either a pulse or Doppler measurement. The inherently greater Doppler accuracy is accounted for during the iterative search by its lower variance.

A survey is run by towing a hydrophone at a near constant depth around the beacon-transponder net. Doppler counts are accumulated continually. Travel time measurements with the pulse sub-system are made at specific locations with the vessel hove to.

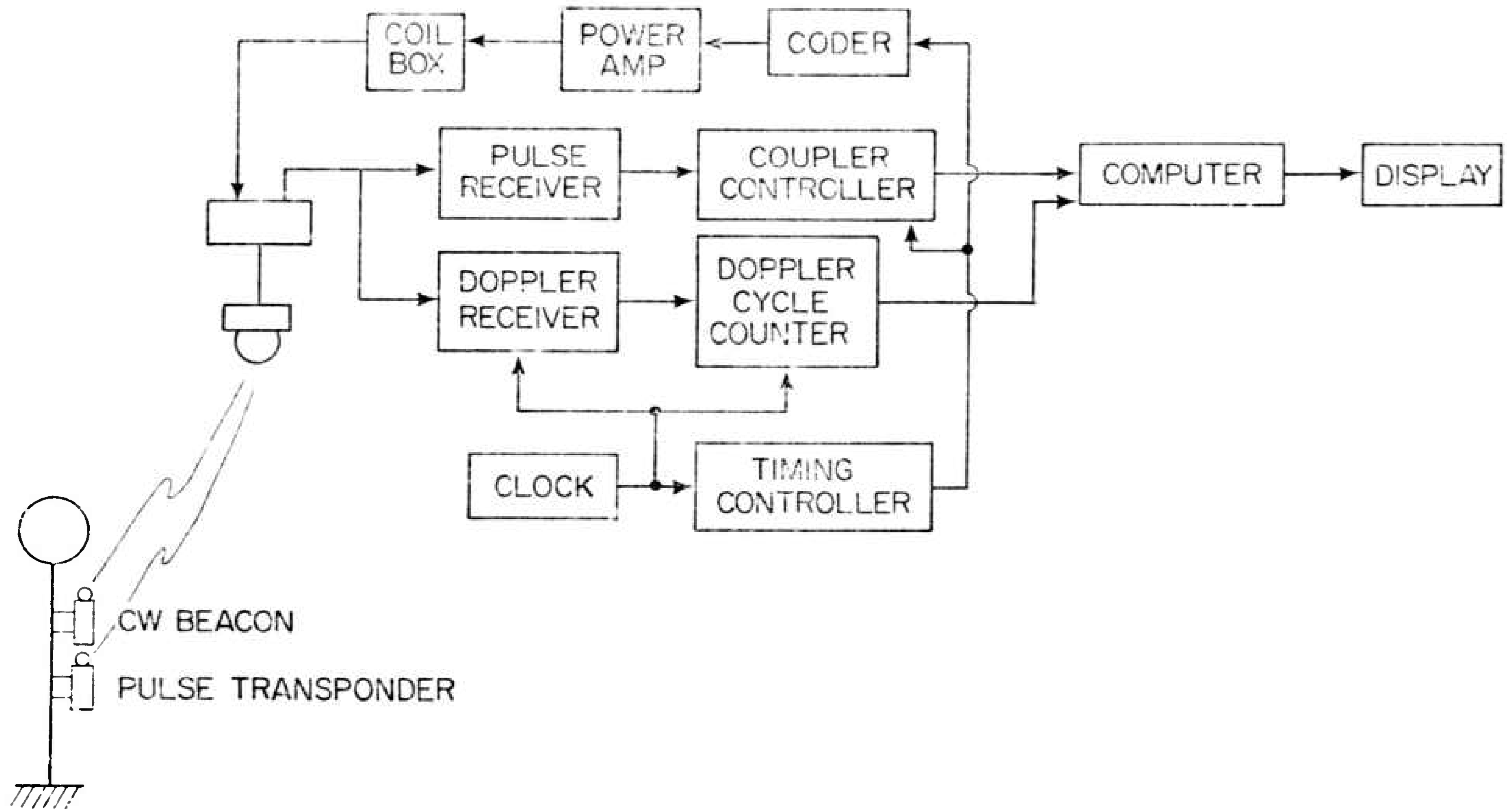
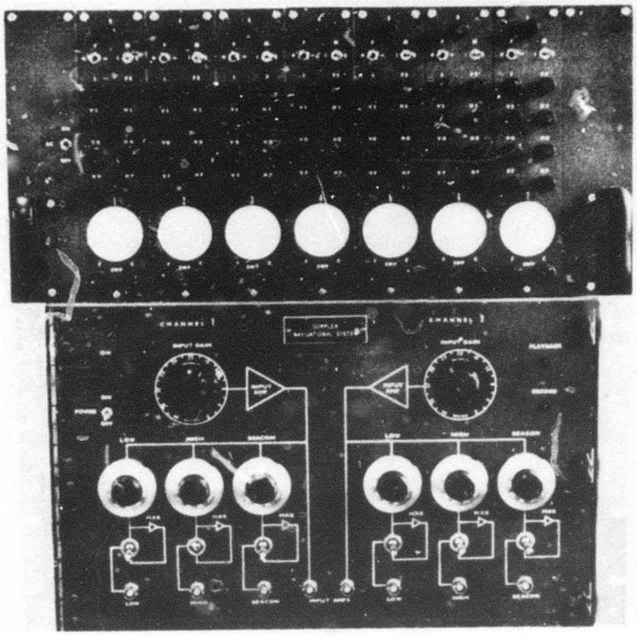
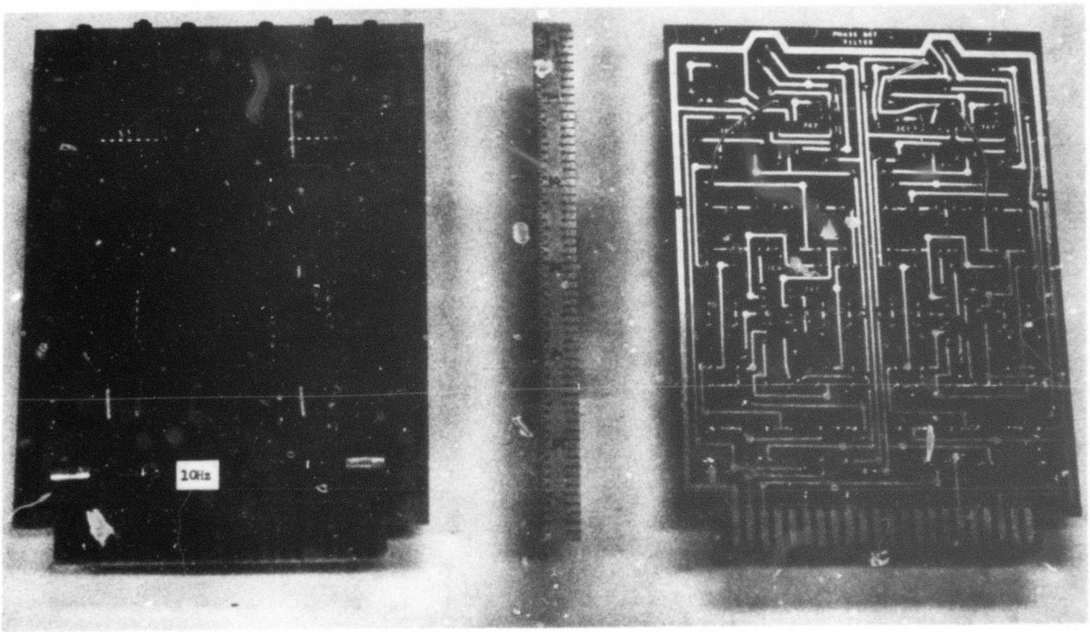


Figure 1. Functional block diagram of Pulse-Doppler System.



a



b

Figure 2. W.H.O.I. Doppler Receiver (a) receiver and monitor, (b) typical circuit card.

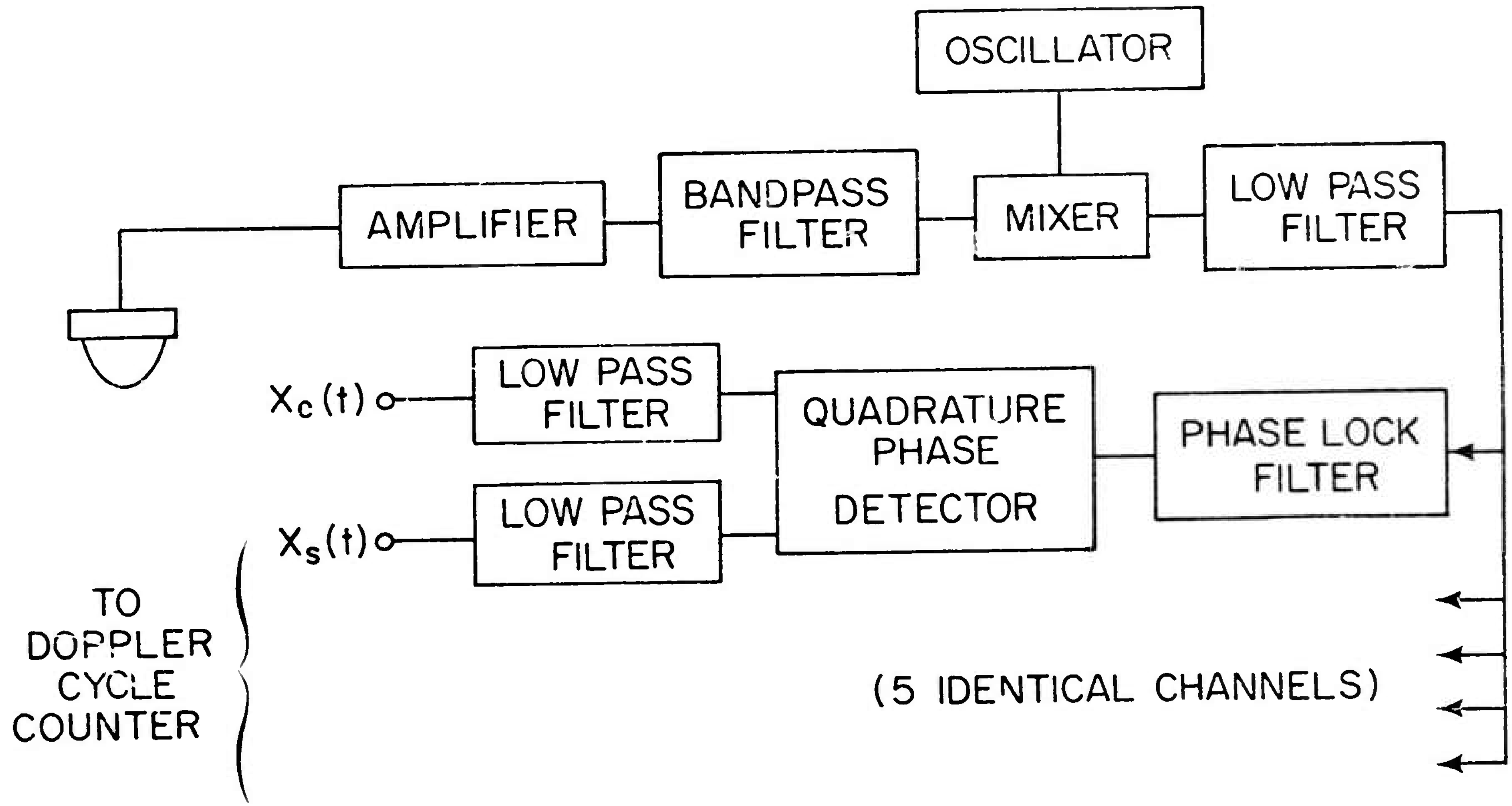


Figure 3. Block diagram of Doppler Receiver.

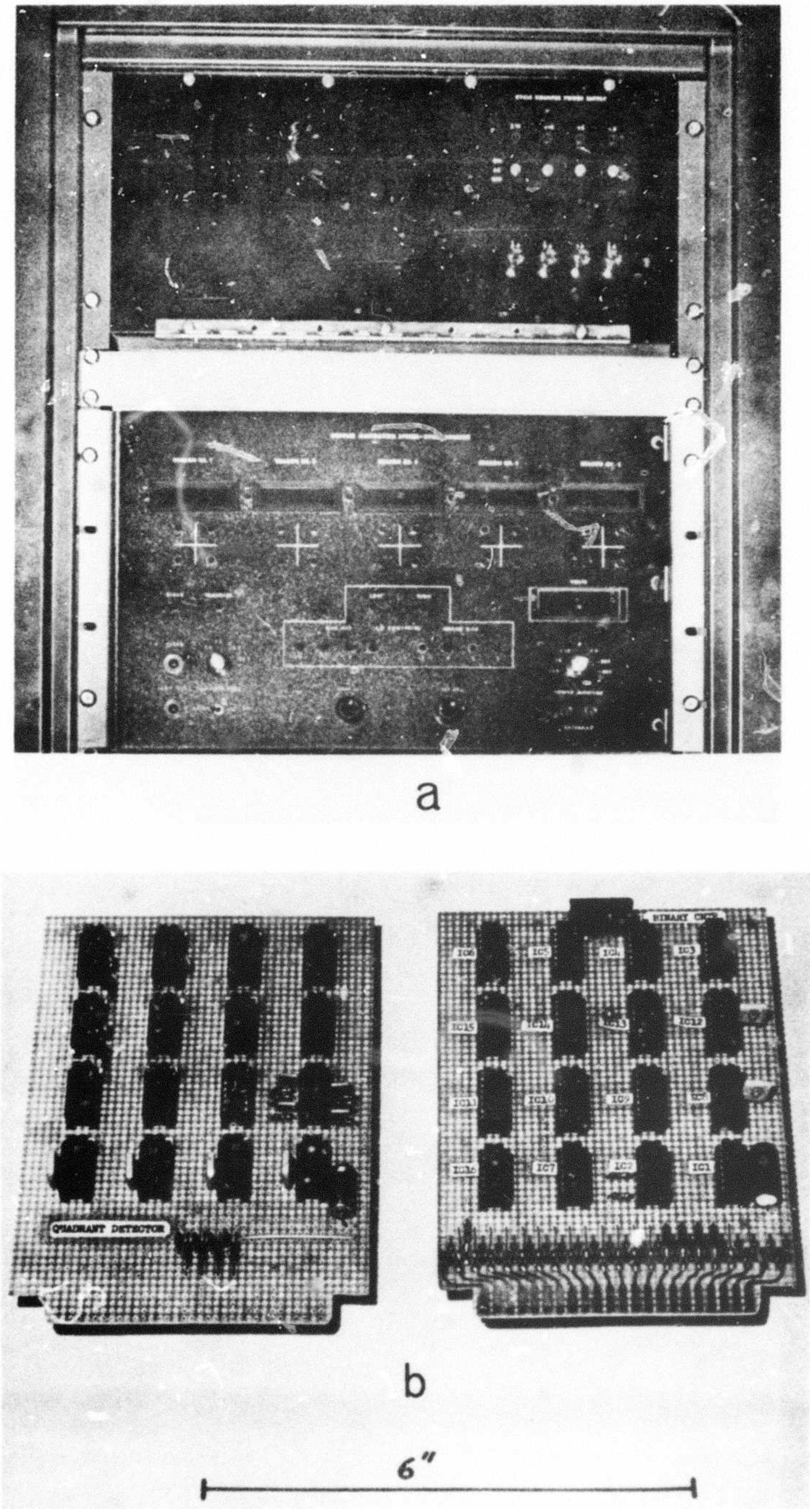


Figure 4. W.H.O.I. Doppler Cycle Counter (a) Cycle Counter and power supply, (b) typical circuit cards.

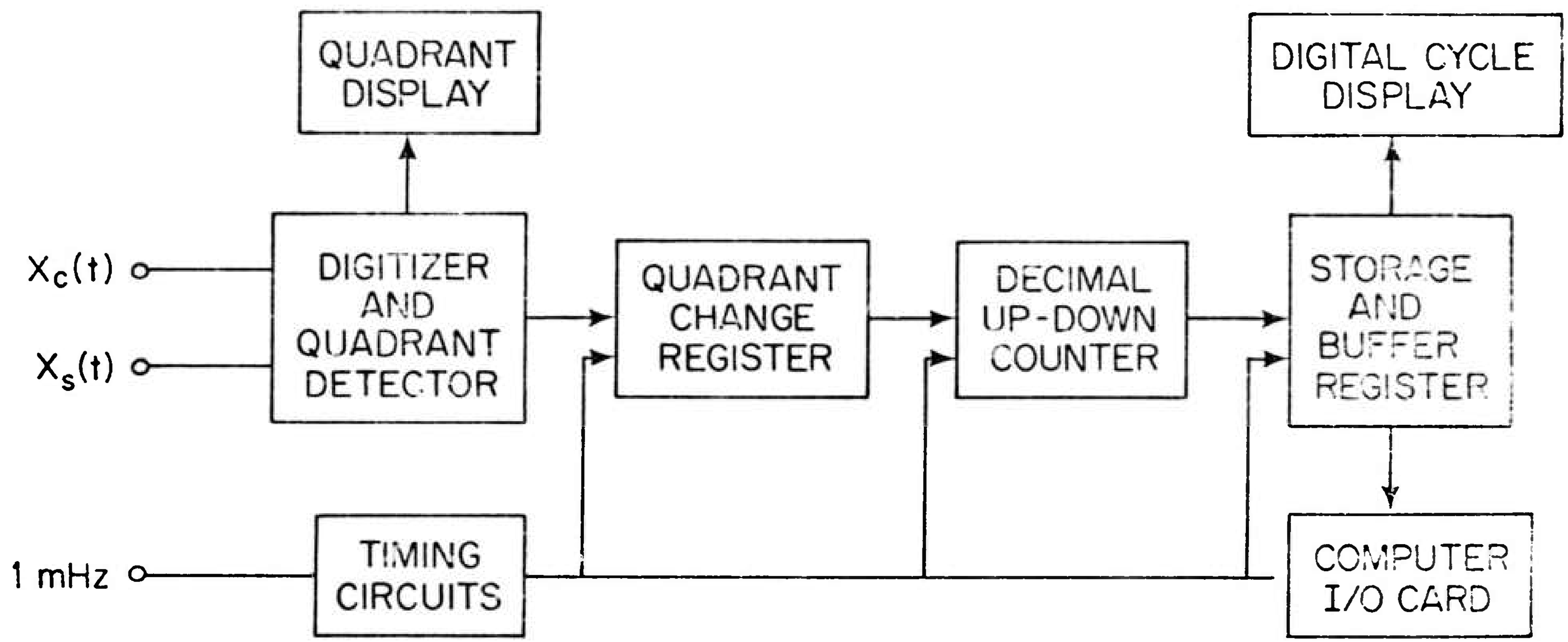


Figure 5. Block diagram of Doppler Cycle Counter.

Self Contained Ancillary Modular Platform
(Optical Command System)

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Self Contained Ancillary Modular Platform

The SCAMP platform was developed to provide a device that would enhance the load carrying ability of the ALVIN submersible. It provides the vehicle with auxiliary power to support various scientific apparatus on the bottom, with or without ALVIN's presence.

Construction Milestones

I. Frame

With SCAMP construction completed except for the optical command system, a mating test was conducted. SCAMP was on the dock at Woods Hole and ALVIN was lowered onto SCAMP. With the exception of a small hold down bracket on ALVIN the mating test was very successful. The guide bumpers guides the ALVIN skids into the rail lock channels and good clearance was obtained in all areas. The ALVIN hold down bracket will be relocated with a minor rework required.

Periodic checks of SCAMP system operation were performed and all functions work very well. Batteries were given equalizing charges and other routine maintenance.

Preparations for towing SCAMP to an area of Woods Hole Harbor are being made to permit bottom suction tests.

II. Optical Control System

The optical command system utilizes a xenon flash and silicon photo cell as transmitter and receiver for a through window command link. Extensive tests of a breadboard system indicated the requirement for some electronic redesign for the final system. During this period that redesign has been done as well as the design required for mechanical packaging of the system components. The light receiver, housing, electronics pressure housing and internal control box designs have been completed. The new receiver design can operate properly with greater than 50 db variation in signal level. The spectral response of the optical transmitter was evaluated and the response of the receiver was approximately matched to this spectrum. The new receiver circuitry was designed to make it less susceptible to other light such as 120 Hz light from fluorescent lights.

An improved frequency detector circuit was designed to inhibit data flow in the receiver unless the incoming signal has the proper frequency components. The number of distinct commands that could be sent was increased from 10 to 100.

In the coming time period the designs are ready for fabrication of the circuit cards, pressure housing, light receiver, light transmitter and control box. After all components are fabricated, bench and simulated water tests are scheduled.

Modular Acoustic System

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Modular Acoustic System

The Modular Acoustic System is being constructed to give ALVIN a wide range of acoustic output frequencies and wave shapes with appropriate receptors. This will increase ALVIN's acoustic capability by many-fold without the necessity of changing anything except the transducers on the outside. The work discussed below is a continuation of the work reported previously.

ALVIN Sonar System

Surface and Submersible Computer Systems

A major effort was made in implementation of the two computer systems during this period. Two major components for the submersible system were purchased: a 16 000 word memory board and a hardware multiply-divide board. Interfaces were constructed and/or programs were written for the following units: keyboard query, keyboard read-in, and echo display; frequency synthesizer; transducer pedestal; analog-to-digital conversion unit; and Ross cassette, as detailed below, and finally some special purpose library routines have been written.

1) Submersible Computer Purchases

Data General made available during early 1974, 16,000 words of memory on a single board - 8,000 having been the previous limit. The small size of the Nova 1210 computer used in the submersible system allows us only one slot for memory. Thus the new board permits the running of programs demanding considerably more memory or the storage of far more data than was possible before. In addition, the 1220 computer used in the surface computer now has a full 16K of memory, necessary for its effective functioning in a disk environment. Previous to this purchase, it was necessary to shift the tow 8K memory boards between the surface and submersible systems as first one and then the other was used.

The purchase of the hardware multiply-divide board was necessary for the implementation of the analog-to-digital conversion capability of the submersible system. The digitization rate is limited by the computer's ability to process and store the digitized data; the new board, by speeding up multiply and divide operations, permits digitization at far higher rates. We presently plan on a digitization rate of 30 kHz, coupled with squaring and adding operations after each digitization.

2) Keyboard Query, Keyboard Read-in, and Echo Display

Submersible system parameters such as acoustic frequency and pulse length are entered by the operating scientist on the keyboard read-in in response to numbered questions appearing on the keyboard query, constructed of LEDs. Up to six of the more important responses are stored on the LED echo display. The interface for query, read-in and display has been constructed and successfully tested with the package known as LEDPK. LEDPK is a collection of subroutines in assembly language operated by calls in other programs such as IMP and SEEK (described in the prior semi-annual report).

3) Frequency Synthesizer

The synthesizer is driven by the programs IMP and SEEK. Earlier we reported its successful operation when parameters (e.g.,pulse length) were entered by toggling the switches on the front panel of the 1210 computer - an interim solution. We can now report that LEDPK has been added to both IMP and SEEK, permitting query, read-in and display of parameters for those programs. The combination of keyboard hardware and interface synthesizer, and the modified programs IMP and SEEK has been tested successfully.

4) Transducer Pedestal

One of the intended modes of operation of the transducer pedestal is under computer control of azimuth and elevation. Position settings selected by the operator cause the transducer to train until the actual pedestal position, as indicated on front panel digital readouts incorporated in the display, coincides with the selected positions. The pedestal interface has been wired but not tested since the display chassis has not been completed. The subroutine package intended to control the pedestal is known as MNTPK. It has been written, but has not yet been incorporated in the main programs IMP and SEEK.

5) Analog-to-Digital Conversion

Conversion of acoustic returns to digital form is necessary to implement the spectral capabilities of the submersible system. We have acquired an analogic module containing a 12-bit analog-to-digital converter and addressable multiplexer. The boards for the module and its associated microprogrammer have been designed, wired, and installed behind the acoustic receiver. The microprogrammer, of our design, supplements the multiplexer; it counts down a 100,000 Hz reference signal from the synthesizer, providing digitization signals for each of up to five channels. These channels correspond to each of the separate frequencies found in the pulse train which is produced by the synthesizer. In addition, the micriprogrammer under computer direction sets up the proper number of channels for digitization in the multiplexer, as well as their order of accessing. This setup occurs only once, relieving the computer of the task of continually updating the multiplexer.

The remaining interfacing is provided by logic elements provided on the 4040 interface board as supplied by Data General.

The conversion unit has not been tested. It will operate under computer control using a set of subroutines known as DIG. These subroutines have been outlined but not written.

6) Ross Cassette

The cassette unit has been fully tested with its interface board under computer control; these tests revealed inadequacies in its servo system requiring factory modifications. These have been made.

A diagnostic program for the Ross units has been written and operates satisfactorily. This tests the stop, fast forward/rewind, abort, and fast/slow speed capabilities. A bite of the operator's choosing can be outputted to the Ross for a selected number of times. Two read options permit further analysis of possible cassette malfunctions.

The two cassette routines called CDLPK and CBOOT, which were reported earlier, have been grouped with three others to form the set of five programs known generically as TOPPK. All are concerned with cassette transfer. CBDMP is employed in the 1220 computer alone and provides a means of putting CDLPK onto cassette. KBBLT and KBBLR are abbreviated versions of Data General's basic binary loader for paper tape (T is for the teletype version, and R for the high-speed reader version). They were developed so that we could have both paper tape and cassette binary loader capability in the 1220 (surface) computer at one time. TOPPK should now comprise a complete set of programs for simple cassette operations.

7) Library Routines

Certain operations such as the conversion of binary-coded-decimal data to binary form occur repetitively in our software. A set of such routines in assembly language has been written for our internal use. They include other data conversions, a general purpose pointer and counter, and a mask operation. The set of library routines is known as KLIB.

Wide Area Illumination

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Wide Area Illumination

The concept of wide area illumination as a technique for better submersible viewing is being evaluated using a power package, a quartz iodide lamp and a xenon gas arc lamp designed for installation on ALVIN.

Construction Milestones

I. Power Pack

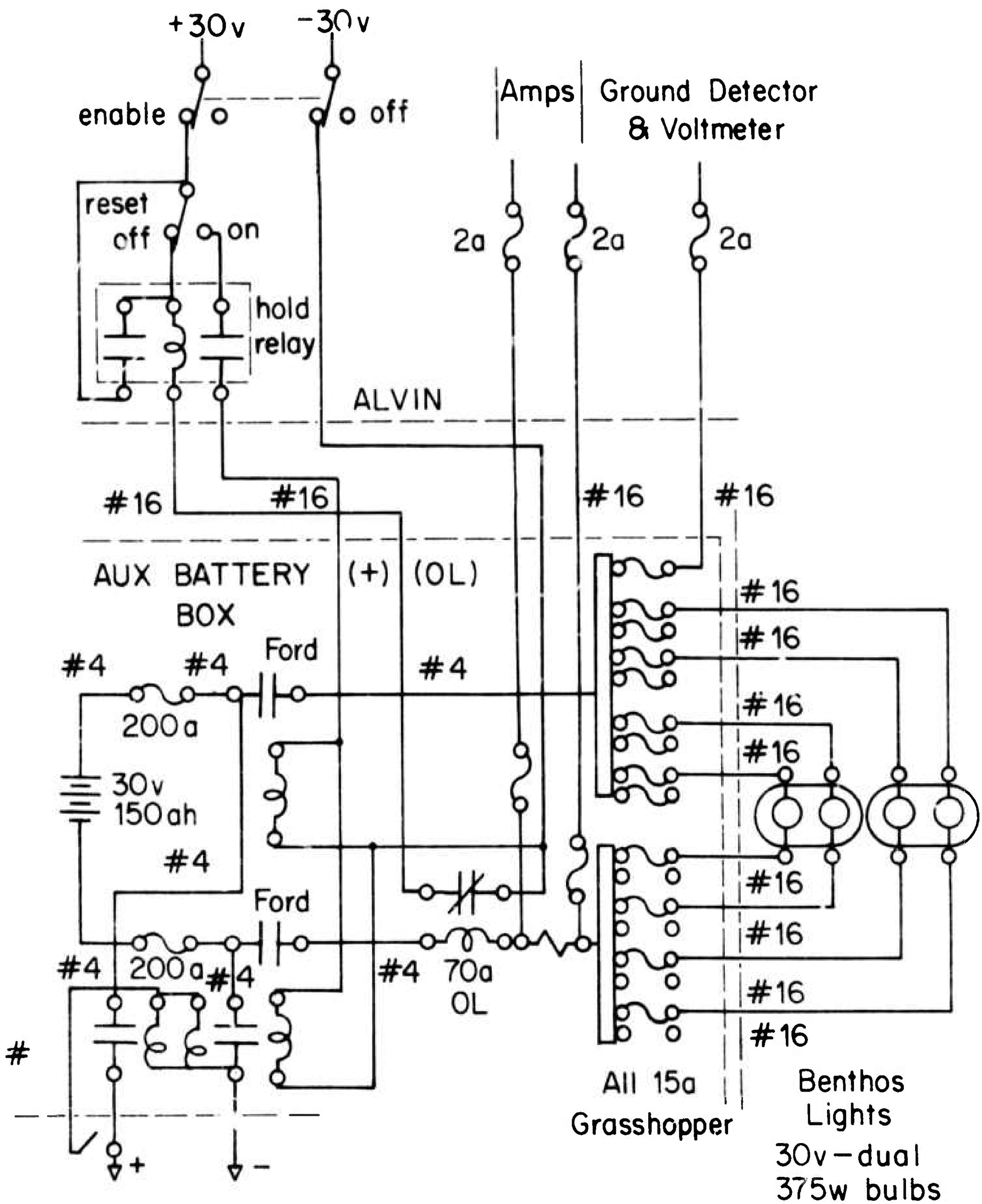
A 30 volt DC lead acid battery pack has been designed for addition to the submersible ALVIN. The pack uses standard ALVIN batteries with a 150 amp hour capabity. A fiberglass and aluminum oil filled box has been manufactured and all wire, connectors, contactors and fuses are on hand for completion. The frame has been fitted to ALVIN and the fiberglass skin of ALVIN has been modified to accept the battery pack. Control of the pack is from within ALVIN and is shown in the attached schematic.

II. Quartz Iodide Light Pack

Two quartz iodide 30 V, 750 watt lights have been purchased and material for a syntactic float is on hand. Fabrication of this pack is continuing. The syntactic float will also be used for the xenon gas arc lamp.

III. Xenon Arc Lamp

A "Streamlite - 1 Million" xenon arc lamp has been purchased and repackaged in an underwater configuration. Some adjustments were required to obtain better heat dispersion without using the fan from the original package. Special consideration was also required in high voltage isolation particularly with regard to underwater connectors. The lamp is working on the bench and final packaging is planned for the next report period.



AUXILIARY BATTERY
& LIGHT